Recent change of alpine vegetation and plant species richness in the Swedish Scandes

By Leif Kullman - Department of Ecology and Environmental Science, Umeå University, SE-901 87, Umeå, Sweden. e.mail: leif.kullman@emg.umu.se

Introduction

This paper highlights results from monitoring studies in the southern Swedish Scandes, which are integrated into a long-term, regional network (Kullman 2001, 2004, 2006, 2007a,b, 2008, 2009; Kullman & Öberg 2009). Unfortunately, lack of funding meant that this unique observation programme had to be discontinued last year. This is highly regrettable, since it is increasingly evident that projections of future trajectories of the alpine and subalpine plant cover cannot entirely rely on manipulative field experiments and space-for-time substitute studies. Long-term observational time series, preferably in combination with paleoecological studies, are mandatory and invaluable for the purpose of ecological modeling.

Climate change

Since the early 20th century, summer and winter air temperatures have increased by 1.3-1.4 °C in the southern Swedish Scandes. Concomitantly, mountain glaciers have receded to their smallest extent over several past millennia and permafrost has ceased to exist. This implies a new climatic regime and a break of a millennia-scale trend of climate cooling and biological impoverishment.

Vegetation change

From a landscape ecological perspective, the most important change relating to recent climate change is treeline rise. The dominant tree species, viz. *Betula pubescens ssp. czerepanovii, Picea abies* and *Pinus sylvestris* have displayed regional-scale treeline rise by a common maximum of about 200 metres since around 1915. In most places, the upshifts are smaller, which relates to prevailing topoclimatic constraints. Initially, *Betula* advanced most rapidly, but during the past 30 years, *Pinus* has taken the lead. Obviously, *Betula* cannot take advantage of warming in the driest and most windy habitats. Tentatively, it appears from paleobotanical investigations in the same region that the new and higher treeline of *Pinus* is unsurpassed in a millennial-scale perspective.

Another conspicuous consequence of the recent warming phase is the reduced frequency of late-lying snow patches in the high mountains. Despite increased precipitation, this has made the mountains drier and snow bed plant communities are being replaced by alpine grasslands and deciduous dwarf-shrub heaths (*Vaccinium myrtillus*). To some extent compensatory, new snow bed and mire habitats are being continually shaped by the recession of glacier and semi-permanent snow patches. Alpine and subalpine mires are drying and are increasingly invaded by shrubs and trees. Lichen-dominated alpine grounds have shown tendencies towards increasing cover of dwarf-shrubs, such as *Empetrum hermaphroditum* and *Betula nana*. Overall, the mountains are taking on a lusher and greener face, which also implicates higher ecosystem productivity.

Increasing plant species richness

Studies revisitating sites, based on historical plant distribution records from the early 1950s, have demonstrated a substantial increase in alpine plant species richness. For example, resurveys of summit floras (vascular plants) on four high mountains have revealed raised species numbers by 58, 67, 88 and 156 %, respectively, over the past 60 years or so. The rate of upshifts amounts to 35-45 metres per decade, which exceeds figures reported from analogous studies in other parts of the world. Saplings of tree species, in particular, have spread upslope by about 100 metres per decade, thereby reaching 500-700 metres above the treeline (Figure 1). In contrast to general expectations, no single species has disappeared from the summit floras during the survey period of substantial climate warming.

Figure 1. Vigorous sapling of Betula pubescens ssp. czerepanovii which has established on a frontal moraine close to the lower margin of a rapidly shrinking glacier.

It is particularly evident from the studies summarised here that species have responded individualistically to climate warming. This upsets traditional views on community compositions, biogeographic delimitations systems and successional pathways.

Many of the altitudinally advancing species are traditionally considered as true forest species, rarely (if ever) observed above the coniferous treeline; for example *Anemone nemorosa, Anthyllis vulneraria* (Figure 2)*, Chrysosplenium alternifolium. Polygala amarelle and Pteridium aquilinum.* It is quite remarkable and an unprecedented experience to find a forb like *Epilobium angustifolium* growing on ice cored moraines and even on debris-covered glacier ice (Figure 3).

Figure 2. *Anthyllis vulneraria* has recently spread about 700 metres higher than previously recorded in the southern Swedish Scandes.

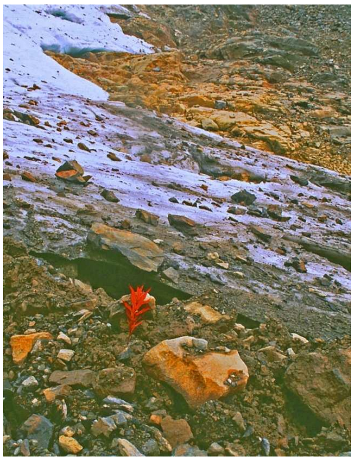

Figure 3. A young specimen of *Epilobium angustifolium* growing in thin morainic debris on glacier ice.This phenomenon has not been previously reported in Scandinavia.

The advent of a fundamentally new climatic regime over the past century is perhaps most strikingly in the establishment of young saplings of true thermophilic (nemoral) tree species such as *Quercus robur* and *Ulmus glabra* (Figure 4) at the transition between subalpine forest and alpine tundra. These species have not been growing here since about 8000-9000 years ago.

Figure 4. Thermophilous *Ulmus glabra* has recently appeared at a site 300 metres higher than the few tree sized specimens which exist in the region.

The results briefly summarised above emphatically contest claims, based on inadequate field research, that intense grazing and trampling by semi-domestic reindeer has concealed attempts of vascular plants to migrate upslope and increase the alpine plant species richness.

The upslope advance of plant species may be facilitated by increased flowering and fruting, which has conspicuously occurred during the past decade or so.

Even if the changes accounted for here turn out to be ephemeral, the magnitude and pace of elevational rise clearly demonstrates that upper distributional limits of plant species do not necessarily lag behind the shifts of climatic isolines. Moreover, there is no conclusive and widespread evidence of retractions of the lower distribution limits of alpine plants, which seem to respond more sluggishly to altered climatic conditions than the upper limits. In fact, results obtained so far implies that the ranges of many species have actually increased in response to climate warming. This argues against the reiterated idea of pending mass extinction of mountain species in case of continued climate warming.

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